CHAPTER 3

# ADAPTATION AND MITIGATION

## DEFINITIONS

### The "Four Laws of Ecology"

Over thirty-five years ago, American ecologist Commoner (1971) proposed Four Laws of Ecology in his book entitled "The Closing Circle". According to Commoner, "an effort has been made to develop this view [i.e., the laws] from available facts, through logical relations, into a set of comprehensive generalizations. In other words, the effort has been scientific" (p. 42).

These general observations about nature, proffered as laws, were proposed before global warming had become generally recognized as a major problem for society, for climate and the environment. Commoner's laws have, however, proven useful when discussing adaptation and mitigation strategies to cope with climate change and food security in a sustainability context:

**1st Law …** *Everything is Connected to Everything Else.*
"The system is stabilized by its dynamic self-compensating properties; these same properties, if overstressed, can lead to a dramatic collapse" (p. 35).

**2nd Law …** *Everything Must Go Somewhere.*
"One of the chief reasons for the present environmental crisis is that great amounts of materials have been extracted from the earth, converted into new forms, and discharged into the environment without taking into account that everything has to go somewhere" (p. 37).

**3rd Law …** *Nature Knows Best.*
"The third law of ecology holds that any major man-made change in a natural system is likely to be detrimental to that system" (p. 37).

**4th Law …** *There Is No Such Thing as a Free Lunch.*
"In ecology, as in economics, the law is intended to warn that every gain is won at some loss" (p. 42).

It is important that policy-makers at all levels of government keep in mind each of these "laws," as they search for, identify, develop and implement adaptation strategies for coping with the impacts of climate change on food security and implementing mitigation strategies to reduce greenhouse gas emissions. They serve as reminders of the important role of ecosystems not only in the health and well-being of societies but also on the health and wellbeing of other ecosystems on which those ecosystems depend. In a search for effective adaptation and mitigation strategies to enhance food security and produce bioenergy, the four laws can serve as educational and instructive guidelines to policy.

## Food Security and the "Four Laws of Ecology"

When it comes to food concerns, fostering either food security or reducing food insecurity requires serious consideration of each of the four laws of ecology. For example, increasing biofuel production may require removing land from food crop production, which causes food prices in the marketplace to rise, the nutritional status of at-risk populations to decrease, and so forth [Ecology Law 1]. Furthermore, if large dams or irrigation systems are built to increase cash crop production capacity, people are forced to migrate. They may find new lands to cultivate the crops they have traditionally grown, but these new lands, because they are likely to be less fertile (increasingly marginal) than the lands they had been forced to abandon, will produce lower yields [Ecology Law 2].

Ecology Law 3, nature knows best, is well-illustrated by the previous scenario: People are often encouraged or forced to cultivate marginal lands, which are defined as lands that are not suitable for sustainable agriculture because of poor soils, inhospitable terrain, erratic precipitation, etc. Around the globe – and especially in the developing world – pressures to move onto new lands to grow food are increasing, as are pressures for both export and population demands and the marginalization of the poor.

The 4th Law – there is no 'free lunch' – is perhaps the easiest to illustrate. Changes in the ways societies choose to interact with the natural environment often produce winners and losers, relatively speaking. Large-scale cash crop and export-oriented irrigation schemes, for example, are usually implemented in areas with fertile soils, displacing local inhabitants and their traditional ways of coping with their harsh environments. Globalization has also put considerable pressure on local producers because of the cheaper prices for some imports, even though the many drawbacks of an inappropriate reliance on imports --- from concerns over energy consumption in transport to the shuttering of locally owned establishments --- are well-documented. Many such examples exist of situations where policy-makers believed they could “change one thing” but later learned that that one change led to a host of unintended consequences that proved more costly than the benefits they had gained from their policy decisions.

## Adaptation

The IPCC’s officially used operational definition for *adaptation* is as follows:

> ***Adaptation*** *- Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001).*

Adaptation as a response to change must be appropriate to specific hazards or threats in a given period of time; in the same way, an effective adaptation to a real or perceived change in local climate could, over time, become inappropriate as circumstances changes. Importantly, however, some responses to change must be understood as reactive from the outset, because they were based on little forethought or analysis. Mal-adaptation refers to changes in the behavior of an organism (or a society) that prove counterproductive with regard to desired outcomes.

The word “adaptation,” as important as it is to climate policy-makers and researchers, is, however, not defined in the same way by all who use it. Furthermore, for the sake of improved communication and understanding across disciplines and cultures, more people must become aware that several words, including (but not limited to) acclimatization, alteration, accommodation, modification, adjustment, are used as synonyms for adaptation. People must also be aware that these alternate terms, while synonymous in some respects to adaptation, do generate different understandings of what is happening in the name of adaptation. To understand the word “adaptation”, Table 3.1 provides a few illustrative

TABLE 3.1

**Selected examples of planned adaptation in the water and agriculture sector (IPCC, 2007b)**

| ADAPTATION OPTION/ STRATEGY | UNDERLYING POLICY FRAMEWORK | CONSTRAINTS | OPPORTUNITIES |
|---|---|---|---|
| Expansion of rainwater harvesting; water storage and conservation techniques; water reuse; desalination; water-use and irrigation efficiency | National water policies and integrated water resources management; water-related hazards management | Financial, human resources and physical barriers | Integrated water resources management; synergies with other sectors |
| Adjustment of planting dates and crop variety; crop relocation; improved land management, e.g. erosion control and soil protection through tree planting | R&D policies; institutional reform; land tenure and land reform; training; capacity building; crop insurance; financial incentives, e.g. subsidies and tax credits | Technological and financial constraints | Access to new varieties; markets; longer growing season in higher latitudes; revenues from 'new' products |

examples of planned adaptation options, underlying policy frameworks, constraints and opportunities in the water and agriculture sector (IPCC, 2007b). They have a direct relevance to food security.

## Mitigation

The 2nd Law of Ecology – everything must go somewhere – relates directly to the awareness that emitting greenhouse gases into the atmosphere in increasing quantities ad infinitum will have a major visible effect in the not too distant future on climate, ecosystems and societies. Adverse signs are appearing around the globe that strongly suggest that rates of change are occurring faster than scientists have been anticipating: most glaciers around the globe are melting, sea level is rising, warm temperature ecosystems are

TABLE 3.2

**Key mitigation technologies and practices in agriculture and forestry, policies and measures, constraints and opportunities (IPCC, 2007b)**

| KEY MITIGATION TECHNOLOGIES AND PRACTICES | POLICIES, MEASURES AND INSTRUMENTS SHOWN TO BE ENVIRONMENTALLY EFFECTIVE | KEY CONSTRAINTS | KEY OPPORTUNITIES |
|---|---|---|---|
| Improved crop and grazing land management to increase soil carbon storage; restoration of cultivated peaty soils and degraded lands; improved rice cultivation; techniques and livestock and manure management to reduce $CH_4$ emissions; improved nitrogen fertilizer application techniques to reduce $N_2O$ emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency; improvements of crop yields | Financial incentives and regulations for improved land management; maintaining soil carbon content; efficient use of fertilizers and irrigation | | May encourage synergy with sustainable development and with reducing vulnerability to climate change, thereby overcoming barriers to implementation |
| Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bioenergy to replace fossil fuel use; tree species improvement to increase biomass productivity and carbon sequestration; improved remote sensing technologies for analysis of vegetation/soil carbon sequestration potential and mapping land-use change; Landfill management and monitoring | Financial incentives (national and international) to increase forest area, to reduce deforestation and to maintain and manage forests; land-use regulation and enforcement | Constraints include lack of investment capital and land tenure issues | Can foster poverty alleviation |

moving upslope into higher altitudes and the areal coverage of Arctic sea ice is rapidly decreasing. As scientists have learned in recent decades where those greenhouse gases are going and what they are doing to the earth's atmosphere and oceans, governments have started to seek ways both to reduce their sources and to increase the sinks for those gases and to prepare for foreseeable adverse impacts.

Mitigation refers to technological change and substitution that reduce energy resource inputs and emissions per unit of output. Although several social, economic and technological policies would also lead to an emissions reduction, for climate change mitigation encompasses implementing policies to reduce greenhouse gas emissions and to enhance sinks. Table 3.2 provides selected examples of mitigation technologies, policies and measures as well as constraints and opportunities for agriculture and forests as outlined in the IPCC (2007b) Synthesis Report. Box 2 provides details of GHG emission and mitigation potential in food and agriculture sector.

A Danish government action program (DANIDA, 2005) defined mitigation in the same words as those of the IPCC: "[mitigation] is an intervention to reduce human-caused net emissions of greenhouse gases." Its report suggested some obvious measures that governments could pursue for mitigation:

- Reduction (at the source) of the use of fossil fuels (clean coal technology, renewable energies)
- Capture of methane from landfills and rice paddies
- Creation of sinks for storing carbon through natural resource management (carbon sequestration) [e.g. reducing tropical deforestation and increasing tree planting] [www.netpublikationer.dk/UM/5736/html/entire_publication.htm]

Mitigation policies, which require identifying effective ways to reduce the amount of greenhouse gases produced and released into the atmosphere, are the first and foremost line of defense for reducing emissions before the worst consequences of global warming are allowed to occur. Although mitigation is the preferred path, it is also perhaps the most difficult to achieve in a way that would have positive global results in a short time. One reason is that implementation of the many suggested mitigation techniques (e.g. transfer of clean technologies, switch to alternative sources of energy (including nuclear), capture and sequestration of carbon and other greenhouse gases such as methane, reduction of fertilizer use, more efficient

BOX 2

**AGRICULTURE HAS POTENTIAL FOR CRUCIAL EARLY ACTION ON MITIGATION**

The land area which is suitable for the production of food, feed, fuel, wood and other products provides a massive carbon store, but is also a source of GHG emissions. The specific aspects and options of GHG emission reductions and enhancing sinks in agriculture and forestry have the potential to mitigate GHGs in food and agriculture.

The Agriculture, Forestry and Other Land Use (AFOLU) sector is responsible for about one third of global anthropogenic GHG emissions. Land use is responsible for 17 percent of the emissions, mainly from deforestation, and agriculture contributes about 14 percent. There is an intimate connection between the different land use sectors, and in many areas agriculture is the main driver of deforestation, leading to GHG emissions.

The forest biophysical mitigation potential was estimated to be 5 380 Mt $CO_2$/yr on average up until 2050 (IPCC, 2001) and agriculture provides a technical mitigation potential of 5 500 to 6 000 Mt$CO_2$-eq/yr by 2030 (IPCC, 2007d). Different forestry and agricultural practices and measures exist which provide mitigation opportunities.

The emissions caused by agriculture can be reduced by more efficiently managing the carbon and nitrogen flows. This can be induced through a change in management practices. For example it is possible to reduce the emissions of $CH_4$ from livestock by increasing the feed use efficiency or from crop production by adopting practices that enhances Nitrogen use efficiency by crops decreasing the emission of $N_20$. The emission reduction potential differs between areas and sectors.

GHG emissions can be avoided or displaced. Fossil fuel energy can in some cases be replaced by bioenergy from wood, agricultural feed stocks and residues and/or the energy efficiency in agricultural sector can be improved. Agricultural mitigation measures often have synergy with sustainable development policies, and many explicitly influence social, economic, and environmental aspects of sustainability. Sustainability criteria need to be applied to ensure sustainable soil and water management and the protection of high biodiversity and nature reserve areas.

Agriculture and forestry have the technical potential for climate change mitigation. The overall challenge is to transform this technical mitigation potential into practice. We have, on a research basis, suitable technologies and farming practices, measurement technologies and experiments with payments for ecosystem services. Approaches to carbon sequestration in smallholder contexts can therefore be developed. Agriculture mitigation practices, such as crop and grazing land management, agroforestry and restoring cultivated organic soils generate high co-benefits for the smallholders, such as raise in productivity, household food security, and increased resilience and ecosystem services. For mitigation activities to become effective a comprehensive landscape approach is necessary.

However, the challenge is to design financing mechanisms for the remuneration of environmental services in the smallholder agriculture. These mechanisms need to provide an incentive for providing and safeguarding ecosystem services such as watershed protection, carbon sequestration and biodiversity provision. For smallholders to be able to participate and benefit from financial rewards and adopt mitigation practices, mechanisms need to be designed which cover up-front investment costs. Institutional set ups are required to aggregate the mitigation reductions across smallholders in order to reduce monitoring and transaction costs.

use of water resources in agriculture and in urban centers) would depend on both the decisions and the will of national policy-makers in industrialized and developing countries alike. Notably, some proposed mitigative tactics (e.g. mirrors in space, iron particles in the ocean, application of reflective particulates in the stratosphere) center on massive planetary engineering schemes that border on science fiction and that could, in turn, result in unintended and even dire consequences.

Numerous plans that include non-engineering solutions have also been proposed by various governmental, intergovernmental and non-governmental organizations to reduce greenhouse gas emissions (specifically $CO_2$ emissions). Carbon trading, for instance, would be a market-based system established between those states that emit greenhouse gases above an allowable country level and those that emit below the amount they are allowed to emit.

Researchers at the World Resources Institute, recently published an article about how to enhance climate change mitigation opportunities in the U.S. agricultural sector that provided useful information and policy options for coping with the emissions of nitrous oxide and methane. The article suggests ways that managers of agricultural operations can reduce their greenhouse gas emissions (WRI, 2007). Policy implications are also noted. The following paragraphs are directly from this article (http://pdf.wri.org/agricultureandghgmitigation.pdf ):

**Nitrous oxide**

*$N_2O$ comes from two main sources—livestock manure and chemical fertilizers. When bacteria interact with ammonia, $N_2O$ is released. Therefore, to reduce $N_2O$ emissions, farmers must decrease either direct emissions of $N_2O$ or the amount of ammonia produced during normal agricultural processes. In dairy and cattle operations, large amounts of ammonia are produced when urea and livestock manure break down in water or slurry. Even greater emissions come from field operations, with the applications of nitrogen fertilizer and related cropping practices.*

*Since fertilizer is responsible for large amounts of agricultural sector $N_2O$ emissions, farmers can choose management practices that lead to appropriate fertilizer application rates. $N_2O$ emissions [can be decreased] by avoiding costly fertilizer over-application.*

**Methane**

*The agricultural sector is, for example, the second largest contributor of $CH_4$ in the United States, with approximately 70 percent of agricultural $CH_4$ emissions coming from enteric fermentation, 25 percent from the decomposition of manure, and 5 percent from rice cultivation.10 Enteric fermentation is a natural process that occurs in the digestive systems of animals such as cattle, sheep, and goats. As much as 7 percent of an animal's* *feed can be lost as $CH_4$, so feedlot operators who increase animal digestive efficiency will save feed costs and decrease methane emissions. Options for increasing efficiency include increasing the daily percentage of highly digestible feed and correcting nutrient deficiencies in livestock diets.*

*Manure stored in central tanks or lagoons also releases $CH_4$ during anaerobic decomposition. However, new technologies now make it possible for this excess $CH_4$ to be captured and either used directly or sold as energy. Capturing the released $CH_4$ and using it for energy effectively reduces GHG emissions, while also helping to meet on-farm energy needs and reduce electricity costs.*

*Finally, rice production is responsible for $CH_4$ emissions from agriculture. These emissions are generated through the cultivation of wet rice, which promotes the anaerobic decomposition of plant wastes that remain after harvest. Reductions in $CH_4$ emissions can be achieved by using different rice cultivars, improving water management practices, and efficient use of inorganic fertilizers.*

### Carbon dioxide

*A majority of these emissions [in agriculture] are related to land-use change (i.e., deforestation), diesel fuel use, and energy used for irrigation and drying of grain. Increasing cultivation efficiency by moving to low-or zero-tillage crop management practices, using more energy-efficient machinery, or reducing energy demand will reduce these direct $CO_2$ emissions. While agriculture emits only small amounts of $CO_2$, it has the capacity to store carbon in plant material and soils. However, this ability to store carbon is limited. Best management practices include conservation tillage, nutrient management, rotational grazing and improved forage management, use of cropping rotations and cover crops, and the establishment of riparian buffers. For farmers to benefit financially from providing carbon offsets using these best management practices, policy-makers will need to develop systems for inventorying and monitoring soil carbon in agricultural lands.*

### Trade-offs

*Inevitably there will be conservation practices that benefit one natural resource while harming another. Leaving water on land under rice cultivation to promote wildlife habitat, for example, can increase wetland* *acreage and enhance wildlife benefits, but can also accelerate the generation of* $CH_4$*. An example with positive benefits is where reduced nitrogen fertilizer applications improves water quality and also reduces* $N_2O$ *emissions. Similarly, riparian buffers enhance wildlife habitat, improve water quality, and increase carbon storage.*

*Conservation practices may also have varying effects on different GHGs. For instance, capturing* $CH_4$ *from livestock manure and urine involves storing the material. Storage reduces the exposure of the urine and manure to oxygen, thus decreasing the release of* $N_2O$*. This illustrates how one conservation practice can simultaneously lead to reductions in two GHGs. Thus, estimating environmental outcomes from conservation practices is important.*

## In Pursuit of Resilient Adaptation to climate change and its impacts

"Resilient Adaptation" is a hybrid concept that merges the best of the suggested practices of resilience and of adaptation in the face of potential hazards and threats from climate change. It includes a safety net or way out of strategies that may, after a while, prove to have been mal-adaptations. It also includes a recovery mechanism that has a degree of flexibility in the face of uncertain future, scientific model-based findings notwithstanding. The concept of resilient adaptation is borrowed from the field of psychotherapy. The editor of a book on the topic suggested "resiliency is operationally defined…as a dynamic developmental process reflecting evidence of positive adaptation despite significant life adversity" (Luthar, 2003). The notion of Resilient Adaptation can be applied to societal as well as individual well-being in terms of climate change assessments on adaptation and mitigation.

## SWOC/T assessment of scenarios for adaptation

SWOC/T assessments are used to evaluate the Strengths, Weaknesses, Opportunities and Constraints (or Threats) of an organization, process or plan. They can also be used as educational tools to assess the prospects and potential pitfalls of strategic responses a government might pursue to counter the adverse impacts of climate change or to derive value from the transformations in the environment that a change in climate might cause. In an open forum, a SWOC/T approach can also help tease out those not-so-obvious aspects of a policy response to climate change's influences on a country's food security. In addition, exposing weaknesses can be useful in a government's preparations for or avoidance of the adverse side effects of a strategy's implementation. In the same vein, identifying both obvious and not-so-obvious constraints is the first step in identifying pathways to remove or overcome them. Although SWOC/T assessments can be valuable learning tools, they will not in and of themselves yield designs for strategic plans to cope with climate change's impacts on food security.

## Scenarios

The creation of scenarios (for example, "Forecasting by Analogy" noted above) is a popular approach to attempt to gain a glimpse of the future, at least the near-term future. Scenarios can help decision makers create contingency plans for possible futures based on past experience. Surprises are to be expected, of course, even though the form they will take may not be known, but scenarios, overall, can be quite useful for hypothesizing about a wide range of potential impacts of a changing climate. As an example, decreases in the area covered by snow and ice in the Arctic are predicted as the earth's atmosphere warms; however, the rates of melting and disappearance of sea ice are now happening much faster than scientists had originally estimated. This means that increased rates of warming can be expected because, unlike snow and ice that reflect a large proportion of solar radiation back into space, ocean water absorbs incoming radiation, forming a positive feedback loop that will result in increasing temperatures.

Scenarios are like contingency plans: They have a limited shelf-life. As an example, 13 months before Hurricane Katrina made landfall in 2005 along the coast of the Gulf of Mexico, destroying the US coastal city of New Orleans, local through national government officials had gathered in the region for an exercise on how to respond to the impacts of a hypothetical Category 3 tropical storm. They called the hypothetical storm Hurricane Pam. Unclear even until now is the extent to which lessons that were allegedly "learned" during the Hurricane Pam scenario exercise were actually followed The US government's initial response (or lack thereof) in the early days of Hurricane Katrina suggests that the Hurricane Pam scenario had little influence on decision making when it was confronted by a real disaster. It appears that the Hurricane Pam exercise had become a distant memory to planners by the time Hurricane Katrina had formed in the Gulf of Mexico.

Nevertheless, scenarios are useful heuristic devices that provide insights to users about the potential demands of structures and functions of institutions and processes. They highlight the potential needs of a society to reduce vulnerability to threats and to increase resilience. Because of their relatively short shelf-life and because societies are constantly changing, however, scenarios need to be revisited, critically reviewed and updated periodically at regular intervals.

## PRIORITY SETTING

### Foreseeability and the Precautionary Principle

Foreseeability is a legal concept used to determine negligence. "In the Law of Negligence, the foreseeability aspect of proximate cause [primary cause of injury] is established by proof that the actor, as a person of ordinary intelligence and circumspection, should reasonably have foreseen that his or her negligent act would imperil others…" [http://legal-dictionary.thefreedictionary.com/foreseeability]. Foreseeability has positive value for its use in terms of climate change.

Foreseeability differs from the concepts of forecast or predictability because it neither depends on nor implies any quantitative description of probability of occurrence. It suggests, for example, that a reasonable person can conclude that certain agricultural practices in certain types of ecosystems, in the absence of any action to change them, will have knowable adverse impacts on environmental quality. Those adverse impacts can lead to such degrading processes as soil erosion, deforestation, fertilizer and pesticide overuse, excessive water diversions, salination of irrigated soils, mechanization of land-clearing activities in increasingly marginal areas, excessive wood gathering for charcoal production for various reasons, and so forth.

These are some of the impacts that occur under today's climate conditions. As the climate warms, however, policy-makers must be prepared to identify and respond to early warning signs of the subtle changes in the local characteristics of their own specific climates. Early warning systems are necessary to alert them to such changes. In addition, they must become increasingly risk-averse in the face of an unknown future. In other words, they must consider using the "Precautionary Principle" when making decisions that might have consequences for food security. The "Precautionary Principle" is a political decision-making approach that emphasizes that a lack of full scientific certainty should not be used as a reason for communities and governments to postpone action to prevent serious and irreversible environmental damage (WLVC, 2003 [http://www.ilec.or.jp/eg/wlv/complete/wlv_c_english.PDF]).

A wide range of climate and climate-related impacts on society can be analyzed through both foreseeability and the "Precautionary Principle." By looking at how climate impacts in recent times have adversely or positively affected food security, for example, governments and humanitarian agencies might effectively determine what characteristics of drought had actually been foreseeable and apply the "Precautionary Principle" the next time those characteristics are identified to mitigate the impacts of future, similar threats. Numerous examples of when existing, reliable information was not used as an impending climate-related food shortage approached and a full-blown food crisis emerged can be cited (Glantz and Cullen, 2003).

## Knowable surprises: surprises that shouldn't be surprising

Arguably, most climate and climate-related surprises are knowable at some level of awareness, especially as scenarios and historical re-enactments better enable the identification of many potential surprises. Myers and Kent (1995) noted:

> *It might seem fruitless to speculate about seemingly unknown problems in the environmental field. But recall that at the time of the first major international conference on the environment in Stockholm in 1972 [UN Conference on the Human Environment], there was next to no mention of what have now become established as front-rank problems: global warming, acid rain and tropical deforestation.*

To this illustrative list of seemingly unknown or unimportant topics could be added, among others, coral reefs, mangroves, desertification and biodiversity.

A central constituent of any of the various definitions of "surprise" is the word "unexpected"; indeed, the concept of the unanticipated is, for most people, fundamental to the characterization of an event as surprising. In this way, surprise relates to the "3rd Law of Ecology" (that Nature knows best) in that societies must respect and accept the fact that scientists are as yet unable to forecast with a desired levels of accuracy the variations and changes of climate and weather on time scales of interest to societies and their leaders. Not surprisingly, therefore, events will befall societies that could not have been anticipated, given our current state of knowledge of the climate system. For example, in 2004 a hurricane, for the first time in history, appeared in the South Atlantic and made landfall on the Brazilian coast. This event was truly surprising.

When trying to forecast surprises to prepare for them, problems often arise because of this reality that the exact timing, intensity, location or duration of events can often not be known or knowable. But climate and weather surprises are not always only physical; they can also arise as a result of perceived impacts. In fact, human perception is a key facet of how societies or groups within societies view the concept of "surprising." It should not be surprising, for example, that as the temperature of the atmosphere increases, some plants will fare well while others will not because, although the exact responses of specific plants remain unknown to researchers, the fact that flora is pretty much temperature and rainfall dependent is elemental biology. Undeniably, many signs have already emerged indicating shifts in the behaviors of a range of plant species with the already-warmed climate. The question, then, is whether or not this constitutes a *knowable surprise*?

Although the phrase sounds a bit contradictory, the fact is that there are knowable surprises, especially if the common usage of the word 'surprise' as opposed to its strict definition is considered. People who live in certain areas around the globe know that droughts are a part of their climate regime, for example. The fact is that drought will come with some frequency, although the exact onset of the next drought and its duration might be unknowable in advance. Similarly, in some areas where locust swarms appear from time to time, governments expect them, though they may still be surprised by the timing of a return, the magnitude and duration of an episode, or the extent of damage to the agricultural sector. The same can be said of flood-or fire-prone areas. The point is that there will always be unknowable aspects to expected events – knowable surprises.

## Invisible boundaries: traditional conflicts involving agriculture

Agriculture has for centuries if not millennia been directly and indirectly involved in various controversies and disagreements (conflicts) related to food security. Often, these controversies are posed as dichotomies, as illustrated by the following non-exhaustive list of traditional agricultural conflicts:

- Agriculture vs. environment
- Intensive vs. extensive agriculture

- Food self sufficiency vs. exports
- Cash crop vs. food crop
- Food crop vs. biofuel crop
- Crops for export vs. crops for domestic consumption
- Globalization vs. localization of agriculture
- Global food security vs. household food security
- Government priorities vs. farmers' (patoralists') priorities
- Open rangelands vs. feedlots
- Trans-border migration for earnings Vs. trans-border migration to sustain livelihoods (eg. herders)
- Cultivated areas vs. rangelands
- Irrigated agriculture vs. rainfed agriculture
- Small scale irrigation vs. large scale irrigation
- Agricultural practices vs. water quality
- Virtual: water for export
- Urban vs. rural food prices
- Agricultural pressures vs preserved areas
- Cultivated areas vs forested areas
- Mangroves and agriculture farms vs. shrimp farms
- Large-scale mechanized fishery vs. small scale fishers
- Existing land use pressure vs. additional pressure from temporary and permanent refugees
- Inorganic agriculture vs. organic agriculture
- Mechanized agriculture vs. small scale indigenous agriculture with traditional draught power
- Agriculture intensification vs. biodiversity conservation
- Biofuels promotion vs. biodiversity conservation
- Genetically Modified (GM) crops vs. traditional crops
- Agricultural failure in conflict zones

Although each of these conflicts/controversies are posed here as simplistic "either/or," zero-sum pairs, the reality is that they all exist in multifaceted interrelationships involving societies, climates, economies, etc. If stakeholders and political gatekeepers can consider how these controversies and conflicts will be affected by global warming, however, win-win solutions could become possible that bring opposing sides together to overcome the challenges that will be generated by warming.

## Invisible boundaries: water-related traditional conflicts and controversies

Similar types of conflicts and controversies can be identified for water. A suggestive list of some of them includes the following:

- Upstream practices vs. downstream practices
- Surface water vs. groundwater
- Rain water harvesting vs. installation of deep tube wells
- Natural flows vs. Reservoirs and dams
- Societal vs. ecosystem use
- Water rights vs. water responsibilities
- Water transfers from surplus to deficit regions
- Irrigation vs. rainfed agriculture
- Virtual water (in-country; exported water)
- Water for agriculture vs. water for urban areas
- Water for agriculture vs. water for eco-tourisms
- Water for agriculture vs. water for industry
- High Yielding varieties vs. traditional crops
- Drainage water vs. storage facilities

A “heads up” warning about how global warming might influence the invisible “frontlines” of these controversies and conflicts can be a first step towards the development of issue-specific anticipatory resilient adaptation strategies. Each of the conflicts or controversies in the list above has generated a considerable body of literature, both peer-reviewed articles and grey literature in the form of government and non-governmental reports.

Given the specter of climate change at local, national and regional levels, populations, disease vectors, animals, fish populations, ecosystems, rainfall patterns, etc. can be expected to shift in time and space. Known patterns of interaction, either peaceful or conflict-laden, can also be expected to change. Such changes, however, if anticipated correctly, can lead to future cooperation as opposed to continuation of existing conflicts. New relationships can be forged. Indeed, the more researchers and policy-makers know about the local to regional changes expected to accompany global warming, the better their opportunities will be to manage potential cooperation and minimize potential or defuse existing conflicts. The specter of continued climate change throughout the rest of the twenty-first century could, in the end, foster a time for immediate, urgent conciliation between competing and conflicting forces and interests.

Given the uncertainties surrounding the science and the potential uses of scientific information in decision-making, making explicit these and other agriculture-related controversies provides an excellent opportunity to pursue disaster-related diplomacy (in this case, disaster-avoidance diplomacy) to shape compromises as protagonists will face the same pressures and uncertain futures as a result of global warming (www.disasterdiplomacy.org).

## Invisible Boundaries: Food, energy and climate

> *Food, energy and climate. For the first time in history, these three are closely linked. Without an understanding of this new reality, countries and the international community lack for the most fundamental policy decisions – decisions that affect access to food for millions of people. (FAO, 2008)*

The high level conference on "World Food Security: Challenges of Climate Change and Bioenergy" has recognized the importance to address the challenges and opportunities posed by biofuels, in view of the world's need for food security, energy and sustainable development. The governments have highlighted the importance of in-depth studies to ensure that production and use of biofuels are sustainable in accordance with the three pillars of sustainable development. Biofuel development must also takes into account the need to achieve and maintain global food security. To foster a coherent, effective and results-oriented international dialogue on biofuels in the context of food security and sustainable development governments need to understand the linkages and controversies surrounding food and fuel. The following list highlights some of the controversies that exist over biofuels.

- Food vs. Fuel
  Corn (maize) is used for much of the ethanol production in the world, and the US, the European Union and other governments have mandated that a certain percentage of fuel include ethanol. As a result, many of the stakeholders in the corn production, marketing and sales chain have reaped financial benefits in sales for biofuel production rather than food production.
- Fossil Fuels vs. Biofuels
  Some biofuels produce less carbon dioxide to the atmosphere than others. Corn used in ethanol production was once believed

to produce less $CO_2$, but now science suggests that more $CO_2$ is omitted if both the production and the use of corn-based ethanol are accounted for. On the other hand, Brazil argues—and science at present supports—which biofuels produced from sugar cane, clearly emits less $CO_2$ than fossil fuels.

- Biofuels vs. “Biofools”
  While some in the bioenergy business tout that biofuels can help lower energy prices as well as dependence on foreign oil imports, others consider them foolish, arguing that biofuels, even by the most generous estimates, will replace only a few percentage points of a country’s total energy consumption. Critics of “biofuels as panacea” see them more as a temporary band-aid than a real solution to the larger problems of fossil fuel consumption.
- Cash Crops vs. Food Crops
  A constant battle is fought between those who want to put arable land (rainfed and irrigated) into the cultivation of cash crops for sale to export markets and those who want to increase food production for domestic consumption. To the list of traditional cash crops must now be added crops that were once grown solely for food consumption but are now mainly diverted for use as feedstock for biofuels.
- High Energy Prices vs. High Food Prices
  Because high energy prices are a major cause of the high cost of food in marketplaces worldwide, a debate currently exists over whether biofuel production increases energy or food prices.
- Agricultural Land vs. Marginal Land
  Those pursuing the development of bioenergy contend that only unused or marginal lands will be used for biofuel production; no land is to be taken away from food production, they claim. That has not been the case for corn or soybeans in the USA and elsewhere, however, as many thousands of acres of productive farmland has been diverted in recent years to produce crops for feedstock and not for foodstock. In addition, some countries are felling trees in once-protected rainforests to develop palm oil plantations for biofuels.
- Affluence vs. Poverty
  Some countries are apparently considering securing large tracts of land in developing areas in order to grow food for their domestic



**SARDINE FISHING IN THE ATLANTIC OCEAN, EL JADIDA, MOROCCO**
*The management strategy for fisheries for a given place must reflect a level of fishing effort given the numerous uncertainties that can surround the exploitation of living marine resources.*

markets because they do not have enough arable land within their borders to meet domestic needs. This is a major ethical issue because, for one example, poverty-stricken, food insecure Africans will soon be growing food for affluent populations, which, especially in Asia, are rapidly growing. What this means is that African subsistence farmers are likely to end up as landless migrants laboring on farms that produce food for other countries.

- Food Security vs. Food Insecurity
  The increasing expansion of biofuel production on land traditionally used to produce food will likely generate food insecurity, even in places where it had not existed before. While biofuels can generate foreign exchange that can in theory be used for development purposes, those funds are often diverted to other pet projects of a country's leaders of politically connected organizations.

## Agriculture-related invisible boundaries are shifting

Controversies and conflicts are dynamic between groups with different competing perceptions about how best to use land or ocean resources. Part of this dynamic often results from government policies. Governments, for example, may encourage cultivators to farm rangelands, displacing pastoralists. But part of this dynamic is likely to be climate-related: During extended drought periods, pastoralists, on the other hand, may be forced to abandon drought-desiccated rangelands and migrate towards wetter cultivated areas, perhaps encroaching into some of the former rangelands that had been overtaken by farmers in earlier, wetter periods. In other words, there can be advances by one side in the controversy and retreats by the other, and vice versa. In another way, one side of a controversy may superficially have "won" the conflict by, for example, dominating a particular swath of land, though in the long run that side may prove to be the biggest loser, having wantonly destroyed a mangrove forest to develop a poorly planned shrimp farm that ended up devastating the ecosystem upon which shrimp populations depended. In all cases, a result to be avoided of human interactions with the environment is one in which, in the long run, "the winner takes nothing."

## Winning and losing in agriculture under a warmer atmosphere

Winning and losing, when applied to climate change, is a controversial topic that requires more clarity. If one were to inform a person in an arid area that there would be an increase in precipitation, at first that person might consider it a "win". However, there is no information about when or how that precipitation might be delivered. If it fell in downpours in one super-storm event, then that increase would not have been considered a win but would be a clear loss. The point is that there has been no attempt to systematically and specifically identify region by region what changes in the aspects of climate might be advantageous to a society and which ones would be harmful.

As noted earlier, government leaders do not usually make decisions based on global statistics and global averages. Agricultural production is a local affair, but trade, aid and comparative advantage make agriculture a global affair. Research suggests that some crops will do well in a somewhat warmer atmosphere, while others will not. Some locations are expected to do better in term of crop yields in a warmer climate, while others will do worse. There are still many unknown factors when it comes to speculation about crop production and crop yields under a warmer climate regime: the hydrologic cycle will intensify, all scientists seem to agree on that, but where, when, and how will that additional precipitation fall? We already know, for example, that crop production is on the rise in, of all unsuspected places, Greenland. So, from the perspective of the Government of Greenland, that is good news; an increase in food self-sufficiency (they can now grow broccoli). The bad news for the government, however, is that Greenland is shrinking in overall size as its ice cover melts.

One can easily argue that, under the current climate (given its average, variability and extremes), different countries, socioeconomic sectors and groups have had identifiable relative (comparative) advantages and disadvantages. This results from an interplay of climatic factors with unique sets of economic, social and political factors. Gains and losses at all levels of society will foreseeably result either from the local climate change itself or from the way that humans respond to that change. Some countries, sectors or groups may have the capability to respond (adapt) to climate change, turning this to their future advantage.

However, with regard to global warming, researchers talk about two phases: a transitional process and an end state. While climate changes in the near term may appear to some countries either as a benefit or a loss, over the long term they argue that there will be no winners. All will lose. Thus, it is also foreseeable that those who benefit in the near term might not fare as well, as the climate continues to warm. So, what might appear a benefit now may turn into a loss in the future, and vice versa. Policy makers must be aware of this possibility.

As noted in the IPCC 3rd Assessment (IPCC, 2001), many rainfed crops in Africa and in Latin America are at their limit of tolerance with regard to temperature. It suggested that productivity in these areas could decline up to 30 percent while productivity of corn in Europe, for example, could increase by 25 percent. Although the 4th Assessment Report states that in the mid- to high-latitude regions, a moderate warming of the climate would benefit crop and pasture yields, even just a slight warming will likely decrease yields in seasonally dry and low-latitude regions [NB: this IPCC projection was made with medium confidence (IPCC, 2007c)]. The point here is that there are knowns, unknowns, and uncertainties about how climate change might affect agricultural productivity, other things being equal, but in most cases other things are never equal.

Once again, the Four Laws of Ecology are relevant: warmer temperatures affect precipitation in time and space as well as evapo-transpiration rates, cloudiness, changed possibilities for pests and invasive species, changes in the characteristics of the seasons, and the need for and development of new technologies and techniques, and so forth. I would suggest that, in general, it is a bit too early to identify all the winners and losers in agriculture, livestock and fisheries, although new evidence of agriculture under a changing warmer climate is constantly emerging.

Participants in a 1990 climate impacts workshop “On assessing winners and losers in the context of global warming” preferred not to talk of winners and losers but to talk of the advantaged and disadvantaged. The former set of terms implied there was an end state in the evolution of human interactions with the changing climate (Glantz, 1990). Yet another, less confrontational, way to describe wins and losses for global warming would be to refer to the “preferential access to food and other resources”.

## Biofuels and early warning systems

In just a few years biofuels have tumbled from their position as the 'darlings' of development (lower cost energy, reduced $CO_2$ emissions, generation of sorely needed foreign exchange, an expansion of trade) to become a solution now collectively scrutinized by a growing number of observers as problematic both for the environment and for long-term development prospects. Today, any discussion that contains the word "biofuels" generates controversy. What seemed like a good idea with win-win consequences for environment and for society, producing energy from biological matter, has unleashed a whirlwind of accusations and finger-pointing, of point and counterpoint, on the benefits and pitfalls of biofuel production and use.

Recent, though post-facto (belated) analyses of biofuels production have raised questions from a climate impacts standpoint about their expected contribution to reducing greenhouse gas emissions. Corn, for example, has changed in the estimation of many from a good crop to a bad crop based on findings of its global warming potential (GWP) alone. Further study has shown that the process of manufacturing corn-based ethanol, as opposed to reducing GHG emissions as originally thought, actually contributes more to greenhouse gas emissions than the burning of most fossil fuels. But large tracts of land have been and continue to be leased for decades or more on the hope and prayer of biofuels' benefits to environment and society: the hope is that biofuel production will lead to prosperity and economic development and the prayer is that investment in land and labor for biofuel production will, on a plant by plant and a case by case basis, withstand a SWOC/T assessment conducted by an independent party.

In retrospect, would the questions elicited by applying the Precautionary Principle about the impacts of biofuels on the environment, society, and the economy and posed in advance of the rush to produce such fuels have revealed some of the late lessons that appear to be emerging despite the early optimism? Would an early warning assessment of biofuels have been of value? Had these conflicts been identified in advance, precautionary steps – a preliminary assessment of potential impacts in the form of a warning system, a feasibility study, or an impacts assessment, for example – could have been taken along the lines suggested by the "Precautionary Principle" before actions too difficult to stop were taken. What remains unclear is the degree to which biofuels will prove to have been a good supplement to the energy needs of countries.

Recently, the emergence of a new group of energy investors has muddled the issue even further. These are speculators and corporations who are entering the energy business in anticipation of sharp, quick gains on their financial investments in the conversion of biological matter into biofuels. Other governments are investing in biofuels to make money to enhance their economic development prospects, often encouraging the involvement of those energy speculators who are providing them with extremely unfavorable investment terms. The well-known truth is that countries in the twenty-first century require energy to function, and energy corporations are reaping enormous profits by setting the terms by which that need is being met. Even though the technologies to meet their capacity demands and the support of a majority of their constituents exist, alternative energies are still not pursued seriously by most governments in an all-out war on dirty greenhouse-gas-producing energy sources in favor of truly cleaner solar and wind energy (and even a serious all-out approach to conservation). Instead, many governments see tremendous potential in growing their own feedstock for biofuel production to relieve domestic pressures on their energy needs. What seems to be going on right now, in essence, is an energy version of a good old-fashioned high-school-style food fight, but instead of the school cafeteria, the battleground is Planet Earth, and instead of students hurling mashed potatoes and cherry pie are “brown-eyed,” “blue-eyed,” and now “green-eyed” energy entrepreneurs fighting for a larger share of the profits to be made in the energy sector, heedless of the fact that someone, someday will have to mop up the mess.

Biofuels have all the markings of a classic “boon to bust” phenomenon. As renowned engineering professor Henry Petroski once wrote, however, “hardly a history can be written that does not include the classic blunders, which more often than not signal new beginnings and new triumphs” (Petroski, 1992). He also suggested that “Failures in turn lead to greater safety margins and, hence, new periods of success”. The image that comes to mind when contemplating today’s energy quagmire is that of deckhands re-arranging the chairs on the Titanic in the minutes after it hit the iceberg. Instead of focusing on how best to save the passengers, the captain and his crew – by analogy, those in the energy business as well as myopic policy-makers – are busy rearranging the deck chairs to obtain a better view of the iceberg that caused the gash in the hull.



**A YOUNG GIRL LEADS HER DONKEY, HEAVILY LADEN WITH JERRICANS OF WATER, THROUGH THE DESERT IN SUDAN**

*The consequences of climate change are complex and far-reaching. Climate change will affect all water-related sectors, including drinking water, agriculture, ecosystems, navigation and hydropower.*